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by

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Environment and Labor Transfer of Skilled Labor and Unskilled Labor between Sectors

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Abstract:

In this paper, we divide the labor into skilled and unskilled labor to investigate the impact that the heterogeneous labor transfer between sectors has on the environment under the international skilled and unskilled labor movements and the price change of the agricultural products. The main conclusions are: under certain conditions, skilled labor inflow deteriorates the environment while its outflow improves the environment; unskilled labor inflow improves the environment while its outflow deteriorates the environment; the increasing price of the agricultural products improves the environment while the decreasing price deteriorates the environment.

Keywords:

Harris-Todaro; Environment; Heterogeneous Labor Transfer; Product Price Change

JEL classification:

O24; Q56; R23

1. Introduction

The transfer of heterogeneous labor force between different sectors is often considered in studies of income disparity and employment. Marjiit and Kar (2005) divided labor force in an economy into skilled and unskilled labor, and established a

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general equilibrium model of a two-sector economy. They studied the income disparity with the assumption that there is no unemployment or flow of capital between sectors. Yabuuchi and Chaudhuri (2007) took skilled labor as a specific factor whereas unskilled labor could move freely between sectors. Based on the assumption of non-existence of unemployment in either sector, they analyzed the impact of international factors on changes of income. Beladi et al (2008) analyzed the impact of inflow of international factors on the wage disparity between the skilled labor and unskilled labor through a two-sector general equilibrium model. This paper is based the assumptions of full employment and free movement of skilled labor between sectors, and existence of unemployment of the unskilled labor. Gupta and Dutta (2010) made an assumption that skilled labor move between trade and non-trade sectors, while unskilled labor do not, upon which they established a general equilibrium model and studied the impact of changes in factor endowments and in price of tradable goods on unemployment and the relative wages of skilled and unskilled labor. Chaudhuri and Banerjee (2010) divided the rural sector into the advanced and the backward subsectors and established a general four-sector equilibrium model. They studied the income effect of capital inflow under the premise of existence of unemployment of skilled labor and immobility of them between sectors, as well as full employment and full mobility of the unskilled labor between the two rural sectors and immobility of unskilled labor between the rural and urban sectors. However, with regard to the real-world economic activities in the developing countries, the impact of the transfer of heterogeneous labor is not limited to income disparity and employment.

On the other hand, since the 1990s, there have been many studies in the academia on the impact of inter-sector labor transfer in developing countries on the environment from different perspectives, particularly the impact of labor transfer on pollution based on the Harris-Todaro Model, such as Beladi and Rapp (1993), Beladi and Frasca (1999), Daitoh (2003), Daitoh (2008), Tawada and Sun (2010), Daitoh and Omote (2011) and Kondoh and Yabuuchi (2012), which involve taxation, environmental policy and improvement of labor market. However, we note that all the aforesaid studies on the labor transfer and environment are based on a common premise, namely, labor is homogeneous, which is different from the reality where labor is actually heterogeneous. As a result, the impact of labor quality on environment is a focus of academic studies in developing countries. Some Chinese scholars pointed out that increasing skilled labor endowment would have an impact of improving the environment.[3] Therefore, we would like to study the impact of the transfer of heterogeneous labor between sectors on the environment.

In this paper, we will divide the entire labor force into the skilled and unskilled sectors and studied the impact of heterogeneous labor transfer between sectors on the environment under the conditions of free flow of international labor factors and change of agricultural products prices. The main conclusion of this paper is that, under certain circumstances, inflow of skilled labor could deteriorate the environment; on the other hand, the outflow of labor could improve the environment. The inflow of unskilled labor would, however, improve the environment; and the outflow would deteriorate the environment. In the following, we will establish an analytical a model in the second part, made a theoretical analysis in the third part, and draw a conclusion thereupon the last part would.

[3] See: Li, P.Y. and Ding L., 2012. Evaluation Index and Multivariate Statistical Analysis of Urban Inhabiting Environment. Journal of Harbin Industry University 5, 116-124.

2. The Model

We consider a small open developing economy with two sectors, namely, the urban sector and the agricultural sector. The economy uses four production factors, which are skilled labor L_S, unskilled labor L_U, capital K and land N. The urban sector uses skilled labor, unskilled labor and capital to produce the import-competing goods. The agricultural sector uses skilled labor, unskilled labor and land to produce exportable goods. The urban sector is skilled labor intensive and the agricultural sector is unskilled labor intensive. The production functions of the urban and agricultural sectors are given by:

$$X_1 = F^1(L_{S1}, L_{U1}, K) \tag{1}$$

$$X_2 = eF^2(L_{S2}, L_{U2}, N) \tag{2}$$

F^1 and F^2 are production functions increasing corresponding to each factor and satisfying linear homogenous and strictly quasi-concave properties.

In the production function of the agricultural sector,

$$e = \frac{\bar{E} - \mu X_1}{\bar{E}} \tag{3}$$

where e represents the environment of the economy. When $e = 1$, the environment is in the best condition. It becomes worse when e decreases. $\bar{E}$ represents the environment endowment when there is no pollution in the economy. μ is the pollution that the urban sector discharges for producing one unit of good. We assume that only the production of the urban sector causes pollution emission to make the environment worse. The harmful substance emitted, such as waste gas, waste residue and waste water, pollute water and soil for agricultural use through atmosphere, rivers and other media. Hence, the product efficiency of the agricultural sector decreases.

Under the condition that the markets are perfectly competitive, we could obtain that:

$$p_1 = a_{S1}w_{S1} + a_{U1}\overline{w_U} + a_{K1}r \tag{4}$$

$$p_2 = a_{S2}w_{S2} + a_{U2}w_{U2} + a_{N2}R \tag{5}$$

Where $a_{ij}(i = S, U, K, N; j = 1, 2)$ represents that the factor i used in producing one unit of goods in the jth sector. w_{S1} is the wage rate of skilled labor in the urban sector. w_{S2} is the wage rate of skilled labor in the agricultural sector. $\overline{w_U}$ is the wage rate of unskilled labor in the urban sector. w_{U2} is the wage rate of unskilled labor in the agricultural sector. r is the interest rate of capital in the urban sector. R is the rent of land used in the agricultural sector. $p_j(j = 1, 2)$ represent the product prices of the urban sector and the agricultural sector, respectively. In this paper, we assume that all the products are tradable and hence the product prices are given internationally.

Generally, developing countries lack skilled labor. Therefore, we assume that skilled labors are fully employed with no unemployment and they move freely between the urban and agricultural sectors. This paper assumes that the wage rate of unskilled labor in the urban sector is given exogenously, which means that it is downward rigid. However, in the agricultural sector, the wage rate of unskilled labor w is fully elastic. We use L_{UU} to denote the number of unemployed unskilled labor in the urban sector and λ to denote the unemployment rate of unskilled labor in this sector. Hence, $\lambda = L_{UU} / L_{U1} = L_{UU} / a_{U1}X_1$. Therefore, in the unskilled labor market equilibrium, the wage rate in the agricultural sector equals the expected wage income in the urban sector, which equals to the downward rigid wage rate $\overline{w_U}$ multiplied by the probability of obtaining a job in this sector $L_{U1} / (L_{U1} + L_{UU})$. Thus, the allocation mechanism of the skilled labor and unskilled labor are shown as:

$$w_{S1} = w_{S2} \tag{6}$$

$$w_{U2} = \frac{L_{U1}}{L_{U1} + L_{UU}} \overline{w_U} \tag{7}$$

Or:

$$(1+\lambda) w_{U2} = \overline{w_U} \tag{7'}$$

The market clearing conditions of the four production factors: skilled labor, unskilled labor, capital and land, could be shown as follows:

$$a_{S1} X_1 + a_{S2} X_2 = L_S \tag{8}$$

$$a_{U1} X_1 + a_{U2} X_2 + \lambda a_{U1} X_1 = L_U \tag{9}$$

$$a_{K1} X_1 = K \tag{10}$$

$$a_{N2} X_2 = N \tag{11}$$

Where L_S, L_U, K, N represent the endowment of skilled labor, unskilled labor, capital and land, respectively.

The basic theoretical model has been built, which consists of nine equations, (3), (4), (5), (6), (7'), (8), (9), (10) and (11). Nine endogenous variables are determined, and they are w_{S1}, w_{S2}, w_{U2}, r, R, λ, e, X_1 and X_2.

3. Environment and Labor Transfer between Sectors

Differentiating the equations (4), (5), (6), (7'), (8), (9), (10) and (11) and writing in a matrix notation, we can obtain the following equation:

$$\begin{pmatrix} \theta_{S1} & 0 & \theta_{K1} & 0 & 0 & 0 \\ \theta_{S2} & \theta_{U2} & 0 & \theta_{N2} & 0 & 0 \\ A & \lambda_{S2}S_{SU}^2 & \lambda_{S1}S_{SK}^1 & \lambda_{S2}S_{SN}^2 & \lambda_{S1} & \lambda_{S2} \\ B & C & D & \lambda_{U2}S_{UN}^2 & (1+\lambda)\lambda_{U1} & \lambda_{U2} \\ S_{KS}^1 & 0 & S_{KK}^1 & 0 & 1 & 0 \\ S_{NS}^2 & S_{NU}^2 & 0 & S_{NN}^2 & 0 & 1 \end{pmatrix} \begin{pmatrix} \hat{w}_{S1} \\ \hat{w}_{U2} \\ \hat{r} \\ \hat{R} \\ \hat{X}_1 \\ \hat{X}_2 \end{pmatrix} = \begin{pmatrix} \hat{p}_1 \\ \hat{p}_2 \\ \hat{L}_S \\ \hat{L}_U \\ \hat{K} \\ \hat{N} \end{pmatrix} \tag{12}$$

And differentiating the equation (3), we can get the following:

$$e\hat{e} + (1-e)\hat{X}_1 = 0 \tag{13}$$

Where " ˆ " represents the rate of change, , $\theta_{ij}(i = S, U, K, N;\ j = 1, 2)$ is the distributive share of factor i in the j th sector (e.g. $\theta_{S1} = a_{S1}w_{S1} / p_1$), $\lambda_{ij}(i = S, U, K, N;\ j = 1, 2)$ is the allocated share of factor i in the j th sector (e.g. $\lambda_{S1} = a_{S1}X_1 / L_S$), $S_{ij}^h(i, j = S, U, K, N; h = 1, 2)$ is the partial elasticity of substitution between factors i and j in the h th sector (e.g. $S_{SU}^2 = \frac{\partial a_{S2}}{\partial w_{U2}} \frac{w_{U2}}{a_{S2}}$), $S_{ij}^h > 0(i \neq j)$ and $S_{ij}^h < 0(i = j)$. We also have:

$$A = \lambda_{S1}S_{SS}^1 + \lambda_{S2}S_{SS}^2 < 0, \quad B = (1+\lambda)\lambda_{U1}S_{US}^1 + \lambda_{U2}S_{US}^2 > 0,$$

$$C = \lambda_{U2}S_{UU}^2 - (1+\lambda)\lambda_{U1} < 0, \quad D = (1+\lambda)\lambda_{U1}S_{UK}^1 > 0.$$

The partial elasticity of substitution between factors plays an important role in the following discussion. Therefore, in this paper, we make the following assumptions:

Assumption 1. $\frac{S_{UK}^1}{\theta_{K1}} > \frac{S_{US}^1}{\theta_{S1}}$

Assumption 1 implies that unskilled labor is more substitutable with capital than with skilled labor in the urban sector.

Assumption 2. $\frac{S_{SN}^2}{\theta_{N2}} > \frac{S_{SU}^2}{\theta_{U2}}$

Assumption 2 implies that skilled labor is more substitutable with land than with unskilled labor in the agricultural sector.

3.1 Labor transfer between sectors under the international skilled labor movement

Skilled labor in developing countries will sometimes leave because of low wages. In reality, there are also some situations in which skilled labor moves to developing countries from outside. Recently, high unemployment rate in some developed countries results in unemployed and retired skilled labor moving to the developing countries to find job opportunities. Therefore, in this paper we not only consider skilled labor outflow, but also their inflow.

We can obtain the following by solving the equation (12):

$$\hat{X}_1 / \hat{L}_S = (\theta_{K1}S^1_{KS} - \theta_{S1}S^1_{KK})\left[\theta_{U2}\lambda_{U2}(S^2_{UN} - S^2_{NN}) - \theta_{N2}(C - \lambda_{U2}S^2_{NU})\right] / \Delta > 0 \quad (14)$$

$$\hat{w}_{S1} / \hat{L}_S = -\theta_{K1}\left[\theta_{U2}\lambda_{U2}(S^2_{UN} - S^2_{NN}) - \theta_{N2}(C - \lambda_{U2}S^2_{NU})\right] / \Delta < 0 \quad (15)$$

$$\hat{r} / \hat{L}_S = \theta_{S1}\left[\theta_{U2}\lambda_{U2}(S^2_{UN} - S^2_{NN}) - \theta_{N2}(C - \lambda_{U2}S^2_{NU})\right] / \Delta > 0 \quad (16)$$

$$\begin{aligned}\hat{w}_{U2} / \hat{L}_S = \{&\theta_{K1}\theta_{S2}\lambda_{U2}(S^2_{UN} - S^2_{NN}) + \theta_{K1}\theta_{N2}\lambda_{U2}S^2_{NS} - \\ &\theta_{K1}\theta_{N2}[B - (1+\lambda)\lambda_{U1}S^1_{KS}] + \theta_{S1}\theta_{N2}[D - (1+\lambda)\lambda_{U1}S^1_{KK}]\} / \Delta\end{aligned} \quad (17)$$

Where Δ is the determinant of the matrix in equation (12) and $\Delta > 0$ (see Appendix).

Using the equations (15) and (17) and Assumption 1, we could get the following:

$$\begin{aligned}(\hat{w}_{U2} - \hat{w}_{S1}) / \hat{L}_S = \{&\theta_{K1}\lambda_{U2}(S^2_{UN} - S^2_{NN})(\theta_{S2} + \theta_{U2}) + \theta_{K1}\theta_{N2}(1+\lambda)\lambda_{U1} \\ &+ (1+\lambda)\theta_{N2}\lambda_{U1}(\theta_{K1}S^1_{KS} + \theta_{S1}S^1_{UK} - \theta_{K1}S^1_{US} - \theta_{S1}S^1_{KK}) - \theta_{K1}\theta_{N2}\lambda_{U2}(S^2_{NN} - S^2_{UN})\} / \Delta > 0\end{aligned} \quad (18)$$

Differentiating the equation $a_{S1}X_1 = L_{S1}$, we could obtain the following from the equations (14), (15) and (16):

$$\frac{\hat{L}_{S1}}{\hat{L}_S} = \frac{\hat{X}_1}{\hat{L}_S} + S^1_{SS}\frac{\hat{w}_{S1}}{\hat{L}_S} + S^1_{SK}\frac{\hat{r}}{\hat{L}_S} > 0 \quad (19)$$

According to equations (13), (19) and $\frac{\hat{X}_1}{\hat{L}_S} = \frac{\hat{X}_1}{\hat{L}_{S1}} \frac{\hat{L}_{S1}}{\hat{L}_S}$, we could get that:

$$\hat{X}_1 / \hat{L}_{S1} > 0 \tag{20}$$

$$\hat{e} / \hat{L}_{S1} < 0 \tag{21}$$

Differentiating the equation $a_{U1} X_1 = L_{U1}$, we could obtain the following equation from the equations (14), (15) and (16) and Assumption 1:

$$\frac{\hat{L}_{U1}}{\hat{L}_S} = \frac{\hat{X}_1}{\hat{L}_S} + S_{US}^1 \frac{\hat{w}_{S1}}{\hat{L}_S} + S_{UK}^1 \frac{\hat{r}}{\hat{L}_S} > 0 \tag{22}$$

According to equations (13), (22) and $\frac{\hat{X}_1}{\hat{L}_S} = \frac{\hat{X}_1}{\hat{L}_{U1}} \frac{\hat{L}_{U1}}{\hat{L}_S}$, we could get that:

$$\hat{X}_1 / \hat{L}_{U1} > 0 \tag{23}$$

$$\hat{e} / \hat{L}_{U1} < 0 \tag{24}$$

With the seven equations (18), (19), (20), (21), (22), (23) and (24) and Assumption 1, we can obtain the following proposition:

Proposition 1. *Under Assumption 1, the skilled labor inflow increases employment of skilled labor of the urban sector and causes the skilled and unskilled labor from the agricultural sector migrate to the urban sector, which deteriorates the environment and decreases the skilled-unskilled wage inequality. Conversely, the skilled labor outflow decreases the employment of skilled labor of the urban sector and causes the urban unskilled labor move to the agricultural sector, which improves the environment and increases the skilled-unskilled wage inequality.*

The urban sector is more skilled labor intensive than the agricultural sector. Therefore, the skilled labor inflow increases the skilled labor endowment in the economy. According to the Rybczynski Theorem, skilled labor inflow leads to an expansion of the urban sector and a contraction of the agricultural sector following the Rybczynski effect. With the unchanged capital endowment, the urban sector should employ more skilled and unskilled labor to increase the output. Hence, the rural skilled and unskilled labor migrates to the urban sector. With the unchanged unskilled labor endowment, the demand for them increases because of the unskilled labor migrates to the urban sector, which decreases the skilled-unskilled wage inequality. The increasing output of the urban sector increases pollution and deterioration of the environment. Conversely, using the same method, we could also analyze the impacts of the skilled labor outflow.

3.2 Labor transfer between sectors under the international unskilled labor movement

We consider the impacts of both the outflow and inflow international unskilled labor on the wage disparity and unemployment rate in the developing countries. Although the former situation (outflow) is common in the developing countries, the latter (inflow) also exists in the real developing economies.[4]

Under Assumption 2, we could obtain the following by solving the equation (12):

$$\hat{X}_1 / \hat{L}_U = \lambda_{S2}(\theta_{S1}S_{KK}^1 - \theta_{K1}S_{KS}^1)(\theta_{U2}S_{SN}^2 - \theta_{N2}S_{SU}^2 - \theta_{U2}S_{NN}^2 + \theta_{N2}S_{NU}^2)/\Delta < 0 \quad (25)$$

$$\hat{w}_{S1} / \hat{L}_U = \theta_{K1}\lambda_{S2}(\theta_{U2}S_{SN}^2 - \theta_{N2}S_{SU}^2 - \theta_{U2}S_{NN}^2 + \theta_{N2}S_{NU}^2)/\Delta > 0 \quad (26)$$

$$\hat{r} / \hat{L}_U = -\theta_{S1}\lambda_{S2}(\theta_{U2}S_{SN}^2 - \theta_{N2}S_{SU}^2 - \theta_{U2}S_{NN}^2 + \theta_{N2}S_{NU}^2)/\Delta < 0 \quad (27)$$

$$\begin{aligned}\hat{w}_{U2} / \hat{L}_U = [&-\theta_{S1}\theta_{N2}\lambda_{S1}(S_{SK}^1 - S_{KK}^1) - \theta_{K1}\theta_{S2}\lambda_{S2}(S_{SN}^2 - S_{NN}^2) \\ &- \theta_{K1}\theta_{N2}\lambda_{S2}S_{NS}^2 + \theta_{K1}\theta_{N2}(A - \lambda_{S1}S_{KS}^1)]/\Delta < 0\end{aligned} \quad (28)$$

Using the equations (26) and (28), we could get that:

[4] See: Frédéric Docquier and Hillel Rapoport, 2012. Globalization, Brain Drain and Development. Journal of Economic Literature 50, 681–730.

$$(\hat{w}_{U2} - \hat{w}_{S1}) / \hat{L}_U < 0 \tag{29}$$

Differentiating the equation $a_{S1}X_1 = L_{S1}$, we could obtain the following from the equations (25), (26) and (27):

$$\frac{\hat{L}_{S1}}{\hat{L}_U} = \frac{\hat{X}_1}{\hat{L}_U} + S_{SS}^1 \frac{\hat{w}_{S1}}{\hat{L}_U} + S_{SK}^1 \frac{\hat{r}}{\hat{L}_U} < 0 \tag{30}$$

According to equations (13), (30) and $\frac{\hat{X}_1}{\hat{L}_U} = \frac{\hat{X}_1}{\hat{L}_{S1}} \frac{\hat{L}_{S1}}{\hat{L}_U}$, we could get that:

$$\hat{X}_1 / \hat{L}_{S1} > 0 \tag{31}$$

$$\hat{e} / \hat{L}_{S1} < 0 \tag{32}$$

Differentiating the equation $a_{U1}X_1 = L_{U1}$, we could obtain the following equation from the equations (25), (26) and (27) and Assumption 1:

$$\frac{\hat{L}_{U1}}{\hat{L}_U} = \frac{\hat{X}_1}{\hat{L}_U} + S_{US}^1 \frac{\hat{w}_{S1}}{\hat{L}_U} + S_{UK}^1 \frac{\hat{r}}{\hat{L}_U} < 0 \tag{33}$$

According to equations (13), (33) and $\frac{\hat{X}_1}{\hat{L}_U} = \frac{\hat{X}_1}{\hat{L}_{U1}} \frac{\hat{L}_{U1}}{\hat{L}_U}$, we could get that:

$$\hat{X}_1 / \hat{L}_{U1} > 0 \tag{34}$$

$$\hat{e} / \hat{L}_{U1} < 0 \tag{35}$$

With the seven equations (29), (30), (31), (32), (33), (34) and (35), Assumption 1 and Assumption 2, we can obtain the following proposition:

Proposition 2. *Under Assumptions 1 and 2, the inflow of unskilled labor causes the urban unskilled as well as skilled labor migrates to the agricultural sector, which improves the environment and increases the skilled-unskilled wage inequality. Conversely, the outflow of unskilled labor outflow increases the employment of* *unskilled labor of the urban sector and causes the agricultural skilled labor migrate to the urban sector, which deteriorates the environment and decreases the skilled-unskilled wage inequality.*

The agricultural sector is more unskilled labor intensive than the urban sector. Therefore, the unskilled labor inflow increases the unskilled labor endowment in the economy. According to the Rybczynski Theorem, unskilled labor inflow leads to an expansion of the agricultural sector and a contraction of the urban sector following the Rybczynski effect. With the unchanged land endowment, the agricultural sector should employ more skilled and unskilled labor to increase the output. Hence, demand for both production factors increase, and both the urban skilled and unskilled labor migrate to the agricultural sector. The decreasing output of the urban sector decreases the pollution and improves the environment. With the unchanged skilled labor endowment, the wage of the skilled labor increases because of the skilled labor migrates to the agricultural sector. At the same time, the wage of the unskilled labor decreases because of the increasing endowment, which increases the skilled-unskilled wage inequality. Conversely, using the same method, we could also analyze the situation of decreased unskilled labor endowment.

3.3 Labor transfer between sectors under the price change of agricultural products

We consider the impacts that the labor transfer between sectors has on the environment under the condition of change of price of agricultural products. We can obtain the following by solving the equation (12):

$$\hat{X}_1 / \hat{p}_2 = \lambda_{S2}(\theta_{S1} S_{KK}^1 - \theta_{K1} S_{KS}^1) V / \Delta < 0 \tag{36}$$

$$\hat{w}_{S1} / \hat{p}_2 = \lambda_{S2} \theta_{K1} V / \Delta > 0 \tag{37}$$

$$\hat{r} / \hat{p}_2 = -\lambda_{S2}\theta_{S1}V / \Delta < 0 \tag{38}$$

Where $V = \lambda_{U2}[S_{UN}^2(S_{SU}^2 + S_{NS}^2) - S_{NN}^2(S_{SU}^2 + S_{US}^2) + S_{NU}^2 S_{SN}^2] - (1+\lambda)\lambda_{U1}S_{NN}^2 - CS_{SN}^2 > 0$.

Differentiating the equation $a_{S1}X_1 = L_{S1}$, we could obtain the following from the equations (36), (37) and (38):

$$\frac{\hat{L}_{S1}}{\hat{p}_2} = \frac{\hat{X}_1}{\hat{p}_2} + S_{SS}^1 \frac{\hat{w}_{S1}}{\hat{p}_2} + S_{SK}^1 \frac{\hat{r}}{\hat{p}_2} < 0 \tag{39}$$

According to equations (13), (39) and $\frac{\hat{X}_1}{\hat{p}_2} = \frac{\hat{X}_1}{\hat{L}_{S1}} \frac{\hat{L}_{S1}}{\hat{p}_2}$, we could get that:

$$\hat{X}_1 / \hat{L}_{S1} > 0 \tag{40}$$

$$\hat{e} / \hat{L}_{S1} < 0 \tag{41}$$

Differentiating the equation $a_{U1}X_1 = L_{U1}$, we could obtain the following equation from the equations (36), (37) and (38) and Assumption 1:

$$\frac{\hat{L}_{U1}}{\hat{p}_2} = \frac{\hat{X}_1}{\hat{p}_2} + S_{US}^1 \frac{\hat{w}_{S1}}{\hat{p}_2} + S_{UK}^1 \frac{\hat{r}}{\hat{p}_2} < 0 \tag{42}$$

According to equations (13), (42) and $\frac{\hat{X}_1}{\hat{p}_2} = \frac{\hat{X}_1}{\hat{L}_{U1}} \frac{\hat{L}_{U1}}{\hat{p}_2}$, we could get that:

$$\hat{X}_1 / \hat{L}_{U1} > 0 \tag{43}$$

$$\hat{e} / \hat{L}_{U1} < 0 \tag{44}$$

With the six equations (39), (40), (41), (42), (43) and (44) and Assumption 1, we can obtain the following proposition:

Proposition 3. *Under Assumptions 1, increase of agricultural product price causes the urban skilled and unskilled labor migrate to the agricultural sector, which improves the environment; conversely, decrease of agricultural product price causes* *the agricultural skilled and unskilled labor migrate to the urban sector, which deteriorates the environment.*

The agricultural sector is more unskilled-labor intensive than the urban sector. Therefore, according to the Stolper-Samuelson effects, increase of agricultural product price raises wage rate of unskilled labor in the agricultural sector, which attracts unskilled labor in the urban sector migrates to the agricultural sector. Increase of unskilled labor employment of the agricultural sector increases the output and the demand for skilled labor in this sector. This also attracts the skilled labor in the urban sector to migrate to the agricultural sector. The decrease of employment of both skilled and unskilled labor in the urban sector decreases the output of the urban sector as well as pollution. Hence, the environment of the economy improves. Conversely, using the same method, we could analyze the impacts of decreasing agricultural product price.

4. Conclusion

This article analyzed the impact of labor transfer between the skilled and unskilled sectors on the environment, considering free flow of international labor factor and price change of agricultural products. Our study expands the practicality of theoretical studies of the impact of labor transfer on the environment. Nonetheless, it is just a beginning, and we shall proceed to the other related topics, such as taxation, environmental policies and labor market reform in our future studies.

Appendix

Under the present model, the dynamic adjustment process for the supply side is as follows:

$$\dot{X}_1 = d_1(p_1 - a_{S1}w_{S1} - a_{U1}w_{U1} - a_{K1}r) \quad \text{(A1)}$$

$$\dot{X}_2 = d_2(p_2 - a_{S2}w_{S1} - a_{U2}w_{U2} - a_{N2}R) \quad \text{(A2)}$$

$$\dot{w}_{S1} = d_3(a_{S1}X_1 + a_{S2}X_2 - L_S) \quad \text{(A3)}$$

$$\dot{w}_{U2} = d_4(a_{U1}X_1 + a_{U2}X_2 + \frac{\overline{w_U} - w_{U2}}{w_{U2}}a_{U1}X_1 - L_U) \quad \text{(A4)}$$

$$\dot{r} = d_5(a_{K1}X_1 - K) \quad \text{(A5)}$$

$$\dot{R} = d_6(a_{N2}X_2 - N) \quad \text{(A6)}$$

Where " . " represents differentiation with respect to time and $d_j (j = 1,2,3,4,5,6,7,8)$ is the positive coefficient measuring the speed of adjustment and $d_j > 0$.

Marshallian adjustment process is assumed for quantities when the demand price differs from the supply price in the goods markets. A Walrasian adjustment mechanism is assumed for the factor prices with the fixed endowment in the factor markets. The determinant of the Jacobian matrix of equations (A1) - (A6) is:

$$|J| = d_1 d_2 \cdots d_6 p_1 p_2 KNL_S L_U \begin{vmatrix} 0 & 0 & -\theta_{S1} & 0 & -\theta_{K1} & 0 \\ 0 & 0 & -\theta_{S2} & -\theta_{U2} & 0 & -\theta_{N2} \\ \lambda_{S1} & \lambda_{S2} & A & \lambda_{S2}S_{SU}^2 & \lambda_{S1}S_{SK}^1 & \lambda_{S2}S_{SN}^2 \\ (1+\lambda)\lambda_{U1} & \lambda_{U2} & B & C & D & \lambda_{U2}S_{UN}^2 \\ 1 & 0 & S_{KS}^1 & 0 & S_{KK}^1 & 0 \\ 0 & 1 & S_{NS}^2 & S_{NU}^2 & 0 & S_{NN}^2 \end{vmatrix}$$

It can also be written as follows:

$$|J| = d_1 d_2 \cdots d_6 p_1 p_2 KNL_S L_U \Delta$$

Therefore, according to the Routh-Hurwitz Theorem, a necessary condition for the local stability of the system is that the determinant of the Jacobian matrix is positive. Hence, it is assumed that the equilibrium in this paper is stable under the condition that $\left|J\right| > 0$. We could obtain that $\Delta > 0$.

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